

Searches for doubly charged Higgs and dark photons in four-lepton final states

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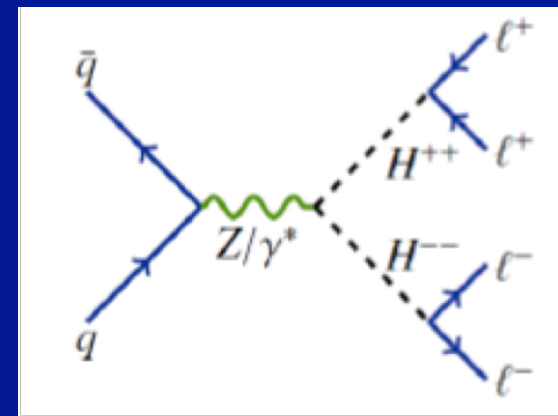
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Motivation

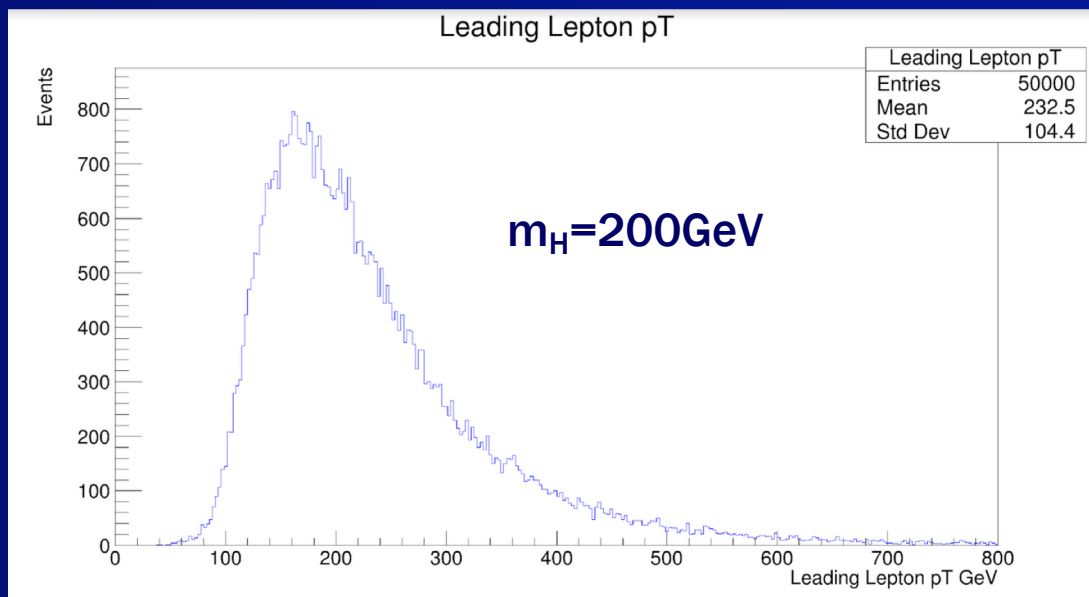
- Exotic searches with 4-lepton (electron and muon) final states can exploit:
 - Clean experimental signature (distinctive signal, low background)
 - Novel trigger capabilities
- Benchmark studies based on two processes:
 - Pair production of doubly-charged Higgs decaying to same-sign lepton pairs
 - Production of dark photons decaying to lepton jets, resulting from
 - Squark pair production
 - Higgs decay to dark fermion pair
- Initially use generator-level simulation to study prospects for HL-LHC at 14 TeV and 100 TeV p-p collider

Initial studies on H^{++}

- Four-lepton signature with same-sign leptons reconstructing Higgs mass
- Left-right symmetric model implemented in PYTHIA [1]
- Plan to investigate necessary pT thresholds and same-sign lepton triggers



ATLAS [2]



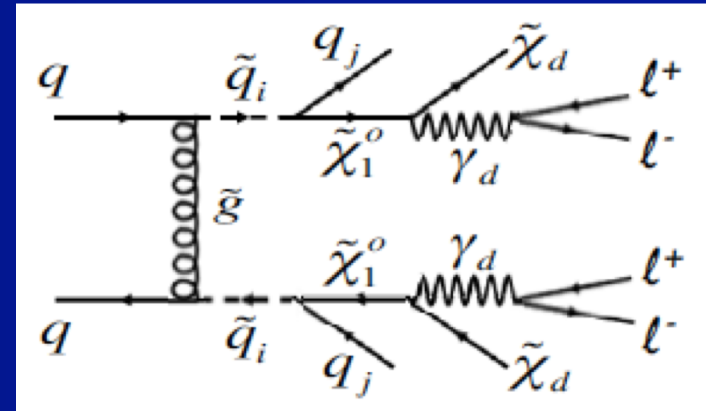
Sensitivity

- Cross section falls nearly exponentially with mass
- For 137 fb^{-1} , expect:
 - ~ 9000 events for $m_H = 200 \text{ GeV}$
 - ~ 200 events for $m_H = 500 \text{ GeV}$
 - < 1 event for $m_H = 1300 \text{ GeV}$
- Main background (ZZ) provides < 1 event of background after a mass cut



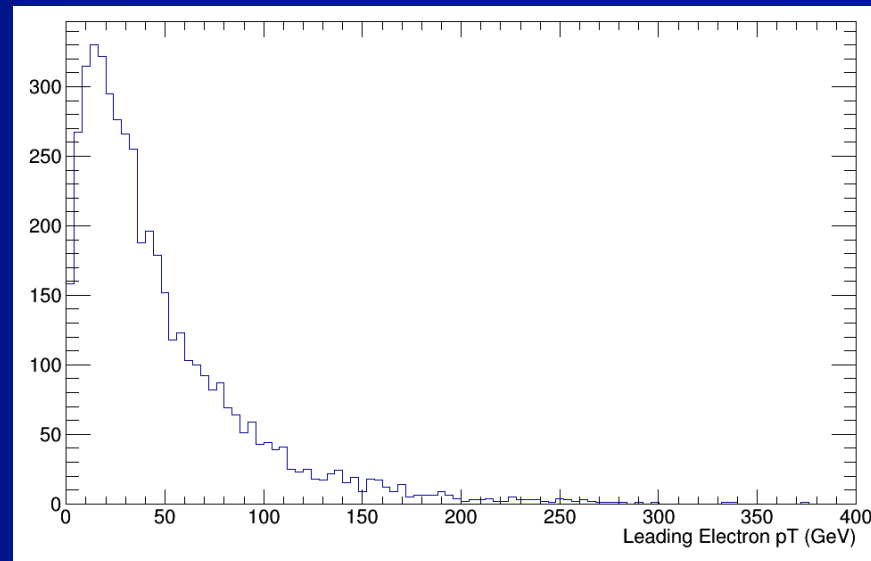
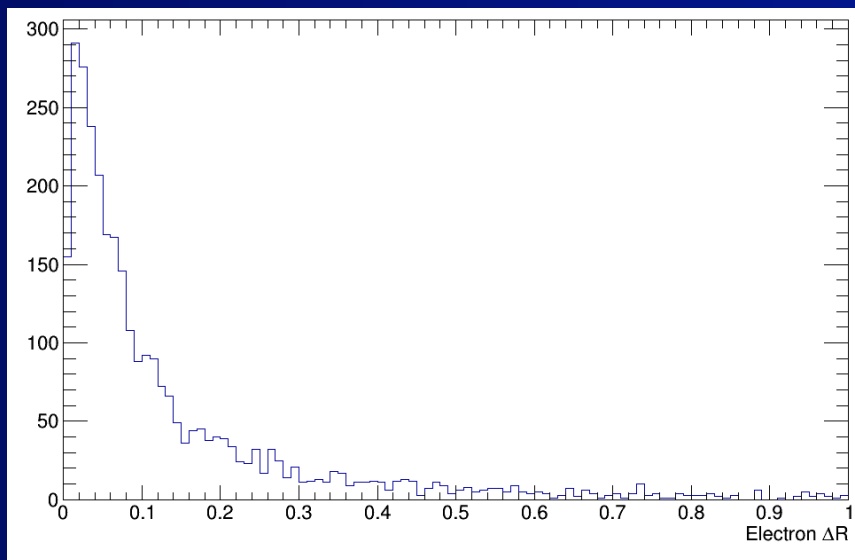
Dark photon decays to lepton jets

- SUSY particles decay to neutralino, which decays into the dark sector
- Dark photons decay to SM leptons via kinematic mixing
- One sample diagram (studied by ATLAS [3]) shown; however:
 - A highly simplified example
 - Most likely, there will be a dark shower with multiple dark photons, depending on dark fine structure constant
 - Dark photons can decay to hadrons (mostly pions) as well as leptons [4]
 - Results in a highly collimated lepton jet with nontrivial hadron contamination



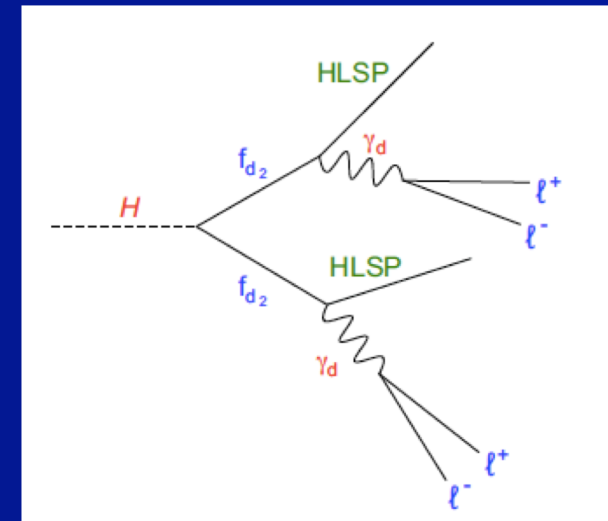
Preliminary lepton-jet studies

- Implemented simplified dark photon production (including showers) in PYTHIA, decaying to electrons only [5]
- As predicted, leptons are close – not isolated
- pT is low, making triggering more challenging
- Track triggering or “scouting” triggers may be helpful



Higgs portal

- Higgs (SM or SUSY) can decay to dark sector particles
- Particles will decay in same dark photon showers
- Lepton jet topology unchanged
- General search for lepton jets should find both production mechanisms



ATLAS [3]

Summary

- Doubly charged Higgs and dark photons both produce distinctive signatures
 - Same-sign invariant mass peaks for doubly charged Higgs
 - Lepton jets for dark photons
- We are able to generate and study these signatures with PYTHIA
- Will move to full simulation studies next
- Goal is to establish mass sensitivities for these models at HL-LHC and other future colliders

References

- [1] K.Huitu, J.Maalampi, A.Pietila, M.Raidal, Doubly charged Higgs at LHC, Nucl. Phys. B 487:27-42, 1997 [arXiv:hep-ph/9606311]
- [2] ATLAS, Search for doubly charged Higgs boson production in multi-lepton final states with the ATLAS detector using proton-proton collisions at $\sqrt{s} = 13$ TeV, Eur. Phys. J. C 78 (2018) 199 [arXiv:1710.09748 [hep-ex]]
- [3] ATLAS, A search for prompt lepton-jets in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector, 10.1007/JHEP02(2016)062, [arXiv:1511.05542 [hep-ex]]
- [4] C. Cheung, J.T. Ruderman, L.-T. Wang and I. Yavin, Lepton jets in (supersymmetric) electroweak processes, JHEP 04 (2010) 116 [arXiv:0909.0290]
- [5] M. Buschmann, J. Kopp, J. Liu, P.A.N. Machado, Lepton jets from radiating dark matter, JHEP 07 (2015) 045 [arXiv:1505.07459]